Proc. Estonian Acad. Sci. Biol. Ecol., 2007, **56**, 4, 290–296

New records of the amphipods *Chelicorophium curvispinum*, *Gammarus tigrinus*, *G. duebeni*, and *G. lacustris* in the Estonian coastal sea

Kristjan Herkül* and Jonne Kotta

Estonian Marine Institute, University of Tartu, Mäealuse 10a, 12618 Tallinn, Estonia

Received 11 April 2006, in revised form 15 September 2006

Abstract. North-American *Gammarus tigrinus* and Ponto-Caspian *Chelicorophium curvispinum* are the most recently arrived exotic species in the benthic fauna of the Estonian coastal sea. *Gammarus tigrinus* was found for the first time in Kõiguste Bay, northern Gulf of Riga, in 2003. The range expansion of *G. tigrinus* was extremely rapid and by 2005 the species was found all over the northern Gulf of Riga. *Chelicorophium curvispinum* was found for the first time near Sillamäe, eastern Gulf of Finland, in 2005. The nearest established populations of these species are located in the Curonian Lagoon, Lithuania. In connection with the range expansion survey of *G. tigrinus* the rare gammarids of the Estonian coastal sea *G. duebeni* and *G. lacustris* were found in marginal coastal habitats, e.g. isolated bays and small coastal pools of the northern Gulf of Riga in 2005.

Key words: nonindigenous, macrozoobenthos, *Gammarus duebeni*, *Gammarus lacustris*, *Gammarus tigrinus*, *Chelicorophium curvispinum*, Baltic Sea.

INTRODUCTION

In recent decades the communities of the Baltic Sea have substantially changed (Elmgren, 1989, 2001). These changes have been usually attributed either to shifts in climate, trophic status of the waterbody (Hänninen et al., 2000; Elmgren, 2001), or biological invasions (Kotta, 2000; Leppäkoski & Olenin, 2001; Leppäkoski et al., 2002a; Kotta et al., 2006b). The number of nonindigenous species has exponentially risen and the ranges of existing exotic species have expanded in the Baltic Sea area (Gruszka, 1999; Leppäkoski & Olenin, 2001; Jazdzewski et al., 2004, 2005; Kotta et al., 2006a). The referred studies suggest that the rising establishment rate in the Baltic Sea area is likely linked to the increasing

* Corresponding author, kristjan.herkyl@sea.ee

instability of the environment either due to shifts in climate and/or eutrophication together with intensifying shipping.

Biological invasions seem to be of great significance especially for benthic invertebrate communities as among 109 nonnative species of the Baltic Sea more than 40% are benthic invertebrates (Baltic Sea Alien Species Database, http://www.ku.lt/nemo/index.html, accessed 27/03/2006). The amphipods *Gammarus tigrinus* Sexton and *Chelicorophium curvispinum* G. O. Sars are among the most recent newcomers in the Estonian coastal sea. The North-American *G. tigrinus* was found in the shallow coastal area of Kõiguste Bay, northern Gulf of Riga, in 2003 (Herkül et al., 2006). The Ponto-Caspian *C. curvispinum* was first recorded in a green algal belt of the Sillamäe area, eastern Gulf of Finland, in 2005 (Kotta et al., 2006a). The nearest populations of both species are located in the Curonian Lagoon, Lithuania (Olenin & Leppäkoski, 1999; Leppäkoski et al., 2002b; Baltic Sea Alien Species Database, http://www.ku.lt/nemo/index.html, accessed 27/03/2006).

As the invasive benthic invertebrate species often tolerate fluctuating environmental conditions and are found in marginal biotopes, a special effort was made to sample coastal semi-isolated habitats. During the sampling campaign in 2005 we found new sites of *G. tigrinus* but also *G. lacustris* G. O. Sars and *G. duebeni* Liljeborg. The two last species have not been found in the Estonian coastal range since the 1960s–1970s (Yarvekyulg, 1979). The aim of this paper is (1) to give an overview of the current status of *G. lacustris*, *G. duebeni*, and *C. curvispinum* in the Estonian coastal sea and (2) to show in more detail the invasion and establishment of *G. tigrinus* in the northern Gulf of Riga.

MATERIAL AND METHODS

The study was conducted in shallow semi-enclosed bays of the northern Gulf of Riga, northeastern Baltic Sea. The prevailing sediment types of the bays are sandy clay mixed with pebbles, gravel, or boulders. The prevailing depths are between 0.2 and 4 m. The area is influenced by a diffuse nutrient load from the moderately eutrophicated Gulf of Riga (Astok et al., 1999). The benthic vegetation is well developed and extensive proliferation of ephemeral macroalgae and the appearance of drift algal mats have been reported from the area in recent years (Paalme et al., 2004; Lauringson & Kotta, 2006).

Benthos samples were collected from about 200 stations in the northern Gulf of Riga in summer 2005 (Fig. 1). A modified Ekman type bottom grab (0.02 m^{-2}) was used for the sampling of benthic invertebrates. Gammarid amphipods were also collected with a hand net from upper coastal reaches and small semi-isolated coastal pools in Kõiguste Bay in summer 2005. Sediment samples were sieved in the field on 0.25 mm mesh screens. The residuals of the samples were stored in a deep freezer at –20 °C and subsequent sorting, counting, and determination of biomass of invertebrate (dry weight g m^{-2}, 60 °C for 48 h) and plant (dry weight g m^{-2}, 60 °C for 336 h) species were performed in the laboratory using a stereomicroscope.

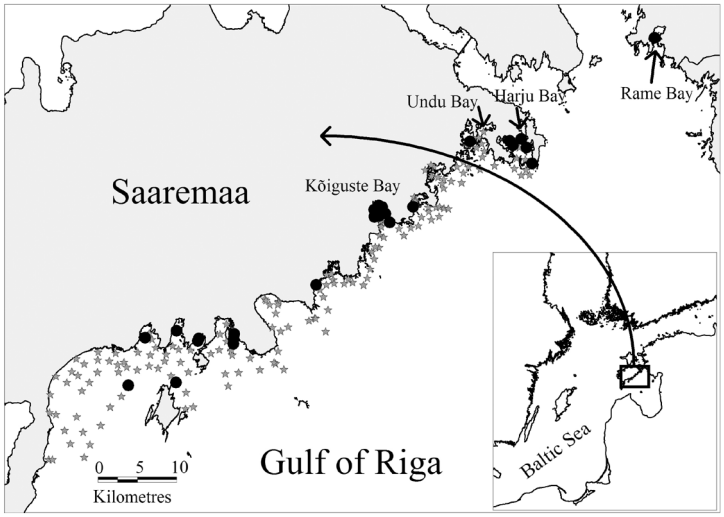

Fig. 1. Study area. Stars indicate sampling stations and filled circles the locations where *Gammarus tigrinus* was found.

Additionally to the described field campaigns in 2005, material for the study was obtained from other macrozoobenthos and macrophytobenthos mapping studies and field experiments (e.g. Estonian Coastal Sea Monitoring Programme, Estonian Marine Institute Database; Kotta et al., 2006a, b)

RESULTS AND DISCUSSION

The amphipod *Chelicorophium curvispinum* is the most recently arrived alien in the Estonian coastal benthic fauna. The species originates from the Ponto-Caspian area and has spread elsewhere mainly through man-made canals and by ship traffic (Bij de Vaate et al., 2002; Haas et al., 2002; Lucy et al., 2004). The species was found in the Baltic Sea already at the beginning of the 20th century (Nikolaev, 1963; Jazdzewski, 1980; Gruszka, 1999). In the northern Baltic Sea *C. curvispinum* was found for the first time near Sillamäe in Narva Bay, eastern Gulf of Finland, in 2005. The nearest population of *C. curvispinum* is located in the Curonian Lagoon, Lithuania (Olenin & Leppäkoski, 1999). Thus, the Sillamäe area is now the northernmost documented location of this amphipod in the Baltic Sea. The species was observed in the depth range of 1 to 4.9 m where the bottom substrate was dominated by sand and boulders. The bottom vegetation was characterized by a belt of the green algae *Cladophora glomerata* (L.) Kütz. and *C. rupestris* (L.) Kütz. with a total coverage of 30–50% and dry weight of 1–79 g m^{-2}. The average abundance and biomass of *C. curvispinum* varied between 125–1425 ind. m^{-2} and 0.05–0.27 g m^{-2}, respectively. The minimum and maximum densities were found

at 4.9 and 3 m depths, respectively. Besides juveniles of gammarid amphipods *C. curvispinum* was the second most abundant taxon at 3 m depth. The salinity in the area is about 4.5.

North-American *Gammarus tigrinus* was introduced to Europe probably in ballast water and was first recorded in England in 1931 (Chambers, 1977). In the Baltic Sea *G. tigrinus* was found already in 1975 (Bulnheim, 1976), but its significant range expansion started in the 1990s (Jazdzewski et al., 2002, 2005; Szaniawska et al., 2003). In the Estonian coastal sea *G. tigrinus* was first found in Kõiguste Bay, northern Gulf of Riga, in 2003. The benthic colonization and community development were studied in a mesocosm experiment in the shallow water area of Kõiguste Bay in 2003. The alien amphipod had colonized several experimental mesocosms, but despite intensive sampling throughout the ice-free season, the species was not observed in regular monitoring stations (Kotta et al., 2006a). In the mesocosm experiment the abundance and biomass of *G. tigrinus* ranged between 100 and 800 ind. m^{-2} and 0.2 and 2.3 g m^{-2}, respectively. In 2003 *G. tigrinus* was also found for the first time in the Gulf of Finland near Hamina (Pienimäki, 2004). In 2004 *G. tigrinus* had already spread all over Kõiguste Bay with densities up to 4700 ind. m^{-2} and biomass reaching 12.22 g m^{-2}. In 2005 the alien amphipod was found all over the northern Gulf of Riga – throughout the southern coast of Saaremaa Island and in Rame Bay, western mainland (Fig. 1). The Curonian Lagoon in Lihtuania is the nearest documented location of *G. tigrinus* (Olenin & Leppäkoski, 1999) and might be the donor region for Estonian population. In the southern Baltic Sea area *G. tigrinus* has caused a dramatic decline of native gammarid fauna (Szaniawska et al., 2003; Jazdzewski et al., 2004; Grabowski et al., 2006). As a euryhaline (Bousfield, 1973), pollution tolerant (Savage, 1996), and highly reproductive (Chambers, 1977) species, *G. tigrinus* has a potential to invade the whole Estonian coastal sea and reduce the native biological diversity.

Gammarus duebeni almost exclusively inhabits very shallow coastal areas and rock pools in the Baltic Sea (Jazdzewski, 1973; Yarvekyulg, 1979; Gaston & Spicer, 2001). The species is highly tolerant of extreme environmental conditions and is able to survive in marginal marine habitats (Yarvekyulg, 1979; Gaston & Spicer, 2001). So far, there has been only one documented record of *G. duebeni* in the Estonian coastal sea. According to Yarvekyulg (1979) *G. duebeni* was found in highly isolated and low saline (2.7) Harju Bay, northern Gulf of Riga (Fig. 1). It was the only amphipod species present at the site. In summer 2005 *G. duebeni* was found in high densities in the upper coastal reaches and small semi-isolated coastal pools of Kõiguste Bay (Fig. 1). The diameters of the pools ranged from about 20 cm to a few metres and depth from a few centimetres to about 20 cm. Based on these observations it is likely that *G. duebeni* is much more common in the Estonian coastal range than previously thought. The under-representation of *G. duebeni* in the samples is due to the fact that no monitoring activities are carried out in the biotopes inhabited by *G. duebeni*.

Gammarus lacustris is a freshwater amphipod found in lakes and rivers of the northern hemisphere (Wilhelm & Schindler, 2000; Vainio & Väinölä, 2003). The amphipod is also common in Estonian lakes (e.g. Timm et al., 2001), but there are

no georeferenced records about *G. lacustris* from the coastal sea. Yarvekyulg (1979) states that *G. lacustris* inhabits isolated bays of the Väinameri Sea without mentioning any specific location. In 2005 *G. lacustris* was found in highly isolated Undu Bay, northern Gulf of Riga (Fig. 1). The bay is characterized by low salinity (1.1–2.5), muddy deposits and dense bottom vegetation of charophytes. The amphipod *G. lacustris* was found at 1–1.5 m depth where the total coverage of bottom vegetation was 85–100%. The biomass of charophytes (*Chara tomentosa* L., *C. aspera* Willd.) reached 3200 g m^{-2}. The zoobenthic community was dominated by Chironomidae larvae (188–3572 ind. m^{-2}, 0.07–0.51 g m^{-2}). In the bay *G. lacustris* was the second most abundant species with a density of 47–423 ind. m^{-2} and biomass of 0.21–0.32 g m^{-2}. Additionally, Plecoptera and Coleoptera larvae were found in the community.

To conclude, the incredible speed and spatial extent of the invasion of *G. tigrinus* suggest that the impact of the amphipod on the native communities is strong and diverse. The high abundance of *C. curvispinum* indicates that the species has probably established in the area and will expand its distribution in the following years. This study also suggests the need of monitoring the semi-isolated water-bodies, e.g. marsh ponds and estuaries that may contain rare species but are likely recipient habitats of new invasive species.

ACKNOWLEDGEMENTS

This study was financed by Estonian Target Financing Program No. 0182578s03 and the Estonian Science Foundation under grants Nos 6015 and 6016.

REFERENCES

Astok, V., Otsmann, M. & Suursaar, Ü. 1999. Water exchange as the main physical process in semi-enclosed marine systems: the Gulf of Riga case. *Hydrobiologia*, **393**, 11–18.

Bij de Vaate, A., Jazdzewski, K., Ketelaars, H. A. M., Gollasch, S. & Van der Velde, G. 2002. Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. *Can. J. Fish. Aquat. Sci.*, **59**, 1159–1174.

Bulnheim, H.-P. 1976. *Gammarus tigrinus*, ein neues Faunenelement der Ostseeförde Schlei. *Schriften des Naturwissenschaftlichen Vereins für Schleswig-Holstein*, **46**, 79–84.

Bousfield, E. L. 1973. *Shallow-water Gammaridean Amphipoda of New England*. Cornell University Press, Ithaca.

Chambers, M. R. 1977. The population ecology of *Gammarus tigrinus* (Sexton) in the reed beds of the Tjeukemeer. *Hydrobiologia*, **53**, 155–164.

Elmgren, R. 1989. Man's impact on the ecosystem of the Baltic Sea: energy flows today and at the turn of the century. *Ambio*, **18**, 326–332.

Elmgren, R. 2001. Understanding human impact on the Baltic ecosystem: changing views in recent decades. *Ambio*, **30**, 222–231.

Gaston, K. J. & Spicer, J. I. 2001. The relationship between range size and niche breadth: a test using five species of *Gammarus* (Amphipoda). *Global. Ecol. Biogeogr.*, **10**, 179–188.

Grabowski, M., Konopacka, A., Jazdzewski, K. & Janowska, E. 2006. Invasions of alien gammarid species and retreat of natives in the Vistula Lagoon (Baltic Sea, Poland). *Helgoland Mar. Res.*, **60**, 90–97.

Gruszka, P. 1999. The River Odra estuary as a gateway for alien species immigration to the Baltic Sea basin. *Acta Hydrochim. Hydrobiol.*, **27**, 374–382.

Haas, G., Brunke, M. & Streit, B. 2002. Fast turnover in dominance of exotic species in the Rhine River determines biodiversity and ecosystem function: an affair between amphipods and mussels. In *Invasive Aquatic Species of Europe – Distribution, Impacts and Management* (Leppäkoski, E., Gollasch, S. & Olenin, S., eds), pp. 426–432. Kluwer Scientific Publishers, Dordrecht, The Netherlands.

Hänninen, J., Vuorinen, I. & Hjelt, P. 2000. Climatic factors in the Atlantic control the oceanographic and ecological changes in the Baltic Sea. *Limnol. Oceanogr.*, **45**, 703–710.

Herkül, K., Kotta, J., Kotta, I. & Orav-Kotta, H. 2006. Effects of physical disturbance, isolation and key macrozoobenthic species on community development, recolonisation and sedimentation processes. *Oceanologia*, **48**, 267–282.

Jazdzewski, K. 1973. Ecology of gammarids in the Bay of Puck. *Oikos Suppl.*, **15**, 121–126.

Jazdzewski, K. 1980. Range extensions of some Gammaridean species in European inland waters caused by human activity. *Crustaceana Suppl.*, **6**, 84–107.

Jazdzewski, K., Konopacka, A. & Grabowski, M. 2002. Four Ponto-Caspian and one American gammarid species (Crustacea, Amphipoda) recently invading Polish waters. *Contrib. Zool.*, **71**, 115–122.

Jazdzewski, K., Konopacka, A. & Grabowski, M. 2004. Recent drastic changes in the gammarid fauna (Crustacea, Amphipoda) of the Vistula River deltaic system in Poland caused by alien invaders. *Diversity Distrib.*, **10**, 81–87.

Jazdzewski, K., Konopacka, A. & Grabowski, M. 2005. Native and alien malacostracan Crustacea along the Polish Baltic Sea coast in the twentieth century. *Ocean. Hydrobiol. Studies*, **34**, Suppl. 1, 175–193.

Kotta, J. 2000. Impact of eutrophication and biological invasions on the structure and functions of benthic macrofauna. *Diss. Biol. Univ. Tartu.*, **63**. Tartu University Press.

Kotta, J., Herkül, K., Kotta, I. & Orav-Kotta, H. 2006a. Invasion history and distribution of the key benthic alien invertebrate species in the Estonian coastal sea. *EMI Rep. Ser.*, **14**, 13–19.

Kotta, J., Kotta, I., Simm, M., Lankov, A., Lauringson, V., Põllumäe, A. & Ojaveer, H. 2006b. Ecological consequences of biological invasions: three invertebrate case studies in the north-eastern Baltic Sea. *Helgoland Mar. Res.*, **60**, 106–112.

Lauringson, V. & Kotta, J. 2006. Influence of the thin drift algal mats on the distribution of macrozoobenthos in Kõiguste Bay, NE Baltic Sea. *Hydrobiologia*, **554**, 97–105.

Leppäkoski, E. & Olenin, S. 2001. The meltdown of biogeographical pecularities of the Baltic Sea: the interaction of natural and man-made processes. *Ambio*, **30**, 202–209.

Leppäkoski, E., Gollasch, S., Gruszka, P., Ojaveer, H., Olenin, S. & Panov, V. 2002a. The Baltic – a sea of invaders. *Can. J. Fish. Aquat. Sci.*, 59, 1175–1188.

Leppäkoski, E., Olenin, S. & Gollasch, S. 2002b. The Baltic Sea – a field laboratory for invasion biology. In *Invasive Aquatic Species of Europe* (Leppäkoski, E., Gollasch, S. & Olenin, S., eds), pp. 253–259. Kluwer Academic Publishers, Dordrecht.

Lucy, F., Minchin, D., Holmes, J. M. C. & Sullivan, M. 2004. First records of the Ponto-Caspian amphipod *Chelicorophium curispinum* (Sars, 1895) in Ireland. *Ir. Nat. J.*, **27**, 461–464.

Nikolaev, I. I. 1963. New introductions in fauna and flora of the North and Baltic Seas. *Zool. Zh.*, **42**, 20–27 (in Russian).

Olenin, S. & Leppäkoski, E. 1999. Non-native animals in the Baltic Sea: alteration of benthic habitats in coastal inlets and lagoons. *Hydrobiologia*, **393**, 233–243.

Paalme, T., Martin, G., Kotta, J., Kukk, H. & Kaljurand, K. 2004. Distribution and dynamics of drifting macroalgal mats in the Estonian coastal waters during 1995–2003. *Proc. Estonian Acad. Sci. Biol. Ecol.*, **53**, 260–268.

Pienimäki, M. 2004. *Gammarus tigrinus*, a new species in the Gulf of Finland. In *The Baltic Sea Portal* (http://www.fimr.fi/en/itamerikanta/bsds/1813.html). Accessed 10/02/2004.
Savage, A. A. 1996. Density dependent and density independent relationships during a twenty-seven year study of the population dynamics of the benthic macroinvertebrate community of a chemically unstable lake. *Hydrobiologia*, **335**, 115–131.
Szaniawska, A., Łapucki, T. & Normant, M. 2003. The invasive amphipod *Gammarus tigrinus* Sexton, 1939, in Puck Bay. *Oceanologia*, **45**, 507–510.
Timm, T., Kangur, K., Timm, H. & Timm, V. 2001. Zoobenthos. In *Lake Peipsi. Flora and Fauna* (Pihu, E. & Haberman, J., eds), pp. 82–99. Sulemees Publishers, Tartu.
Vainio, J. K. & Väinölä, R. 2003. Refugial races and postglacial colonization history of the freshwater amphipod *Gammarus lacustris* in Northern Europe. *Biol. J. Linn. Soc.*, **79**, 523–542.
Wilhelm, F. M. & Schindler, D. W. 2000. Reproductive strategies of *Gammarus lacustris* (Crustacea: Amphipoda) along an elevation gradient. *Funct. Ecol.*, **14**, 413–422.
Yarvekyulg, A. 1979. *Bottom Fauna in the Eastern Part of the Baltic Sea*. Valgus, Tallinn (in Russian).

Kirpvähiliste *Chelicorophium curvispinum*, *Gammarus tigrinus*, *G. duebeni* ja *G. lacustris* uued leiud Eesti rannikumeres

Kristjan Herkül ja Jonne Kotta

Põhja-Ameerikast pärit *Gammarus tigrinus* ja kaspia kootvähk (*Chelicorophium curvispinum*) on Eesti rannikumere fauna kõige uuemad võõrliigid. *Gammarus tigrinus* leiti esmakordselt Liivi lahe põhjaosast Kõiguste lahest 2003. aastal. Kirpvähilise levila laienemine oli erakordselt kiire ja 2005. aastal leidus liiki kogu Liivi lahe põhjaosa rannikumeres. Kaspia kootvähi esmaleid pärineb 2005. aastast Soome lahe idaosast Sillamäe lähedalt. Mõlema liigi lähim asurkond asub Kura säärlõukas Leedus. Seoses liigi *G. tigrinus* levila uuringutega uuriti 2005. aastal marginaalseid rannikuelupaiku, isoleeritud lahti ja väikesi rannalompe Liivi lahe põhjaosa rannikumeres ning leiti kaks Eesti rannikumere faunas harva esinevat liiki: *G. duebeni* ja *G. lacustris*.